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2, 4-Dinitroso-1-Hydroxy-9-Aminonaphthalene-6, 8-Disulfonic Acid as a Sensitive Reagent for Yttrium Ions

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Abstract

A simple and express spectrophotometric method for the determination of yttrium with a new organic reagent 2,4-dinitroso-1-hydroxy-9-amino-naphthalene-6,8-disulfonic acid has been developed. The maximum light absorption of the reagent (λHR = 540) and its complex (λ_MeR = 650 nm) was found.Their structure was studied by IR spectroscopy. The molar ratios of the complex were studied by the Asmus method. The formation and stability of the Y3 + complex with 2,4-dinitroso-1-hydroxy-9-amino-naphthalene-6,8-disulfonic acid was studied by spectrophotometric determination in an aqueous medium. The dissociation constants of the ligand were also studied in an aqueous solution. Spectrophotometric data showed that the metal content in all complexes corresponds to a stoichiometry of 1: 1 = metal: ligand. The formation spectra were used to determine the stability constants of chelates and to determine the optimal pH conditions for obtaining complexes. The developed methods were applied to determine yttrium in the composition of ores.

Keywords:yttrium, 2,4-dinitroso-1-hydroxy-9-amino-naphthalene-6,8-disulfonic acid, spectrophotometry.

INTRODUCTION

Yttrium is used in obtaining sensors (Nguyen et al.2020 and Cherednichenko et al. 2016), superconductors, lasers (Caiet al. 2020) and electrochemical sensors (Shimaaet al 2020). A number of single and jointly doped strontium-yttrium-borate phosphors of ions of trivalent rare-earth elements (europium, terbium, dysprosium) was synthesized by the sol-gel method (Xingyaet al 2017). Composites with dielectric and magnetic properties were obtained with yttrium ferrite, the magnetic properties were analyzed by X-ray diffraction methods, electron density by scanning electron microscopy (Wang et al 2020). When yttrium is added to the WN coating, it also increases its resistance to elastic deformation and plastic deformation before fracture (Graçaet al 2017). Therefore, the development of a new sensitive method for the determination of yttrium is an urgent task in analytical chemistry.

Trace amounts of lanthanides were found in the high-purity matrix of dysprosium oxide (Dy2O3): lutetium (Lu), ytterbium (Yb), thulium (Tm), erbium (Er), holmium (Ho), terbium (Tb), and yttrium (Y) by gas chromatography ... The studies were carried out on C18 and C8 columns with reversed phase using α-hydroxyisobutyric acid (α-HIBA) as eluent, n-octane was used as the ionic interaction reagent (Ye et al 2017). Low yttrium concentrations were determined by fluorescence using balofloxacin. The calibration graph is straight-line in the range from 3.0 × 10-9 to 7.0 × 10-6 mol / L − 1 with a correlation coefficient of 0.9993. The detection limit (3 σ) was determined as 8.3 × 10-10 mol / L-1 (Pranawet al 2013). Chromatographic method determined yttrium using tetra-n-butylammonium hydroxide (TBAOH) using a Kromasil 100 C18 column, as an ionic interaction reagent (IIR), capable of separating yttrium from rare earth elements (REE) in the form of anionic complexes with nitrilotriacetic acid (NTA) (Yuet al2015).

Rare earth elements, yttrium and scandium are determined by atomic emission spectrometry in geological objects (Chumakova 2017), using various carriers. It has been established that there is no universal, highly sensitive, high-precision and cost-effective method for determining the trace amounts of yttrium in any objects. For each specific object of analysis, it is necessary to establish the availability of the material base, the requirements for metrological characteristics, environmental friendliness, rapidity, therefore, the development of new methods for expanding the arsenal of analytical chemist tools does not lose its relevance.

In the determination of yttrium, 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid is a sensitive and selective reagent, since 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid dissolves water and forms a colored complex. The preparation of the complex and the establishment of optimal conditions for the complexation of yttrium were studied by spectrophotometry. This method is characterized by simple hardware design, low cost, sufficient selectivity and sensitivity.

The aim of this work was to develop a new spectrophotometric method for the determination of yttrium in various industrial models. For this, a systematic study of the nature of the interaction of yttrium ions with 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid was carried out.

EXPERIMENTAL PART

We've used a 1 использовали10-3 M aqueous solution of Y (NO) 3; 1·10-3 M solution of 2,4-dinitroso-1-hydroxy-

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9-aminonaphthalene-6,8-disulfonic acid; universal buffer pH 1.81-12.26 (Lurie et al. 1989 and Korostylevet al. 1962). Synthesis and purification are described in (Smanovaet al. 2013).

A valuable property of the reagent 2,4-dinitroso-1-hydroxy-9-amino-naphthalene-6,8-disulfonic acid is the stability of its aqueous solutions. 2,4-dinitroso-1-hydroxy-9-amino-naphthalene-6,8-disulfonic acid is brown in color and melts at 1080C, and at 1430C and above it completely decomposes. It dissolves well in waters and alcohols (Smanova et al. 2014). The individuality of the substance was proved by thin layer chromatography on a *silufol* plate (ethyl alcohol: acetone 2: 1) Rf = 0.72.

Spectrophotometric measurements were carried out on EMC-30PC-UV spectrophotometers. The pH of the solutions was measured on a pH meter pH / mV / TEMP Meter P25 EcoMet (Korea).

Method of determination: 1.0 ml (40 μg / ml) of yttrium solution, 2 ml of 0.001 M reagent solution, 5 ml was added to volumetric flasks with a capacity of 25 ml, 5.0 ml of Britton-Robinson universal buffer (pH 4-5) was added and brought to the volume of the flask with distilled water. The spectra were taken on an EMC-30PC-UV spectrophotometer, l = 1.0 cm, the maximum light absorption of the solution

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RESULTS AND DISCUSSION

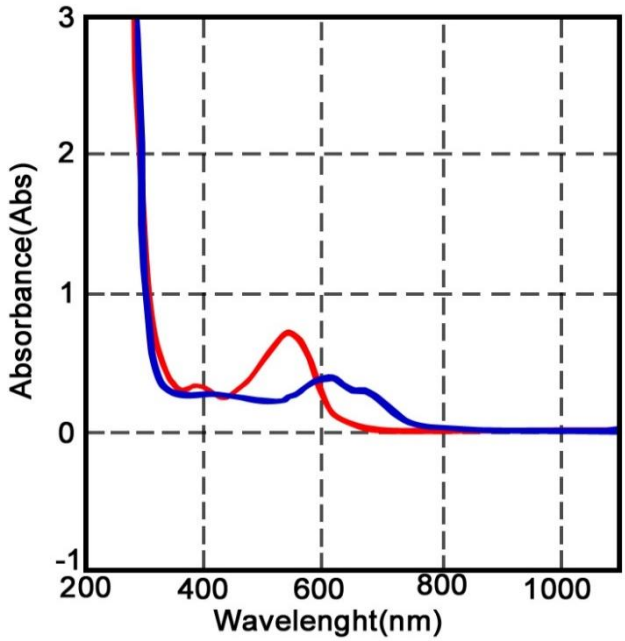


Fig. No: (1): Absorption spectra of 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid and yttrium complex with this reagent.

Yttrium reacts with 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid to form a water-soluble complex that is stable in acidic media, the optimum acidity is pH 4-5. The absorption spectra of a solution of 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid and its complex with yttrium in an aqueous solution are shown in Fig. 1.It is established that the maximum light absorption of the complex is at 520 and 620 nm, contrast is 100 nm.

In order to find the required amounts of reagents that ensure the complete binding of metals into the complex, a series of experiments was carried out in which the concentration of metal ions was maintained constant, and the amount of the reagent was gradually increased. For complete binding of 40.0 μg of Y (III) into complexes, 2.0 ml of a 0.001 M solution of 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid is sufficient, the results are shown in Fig. 2

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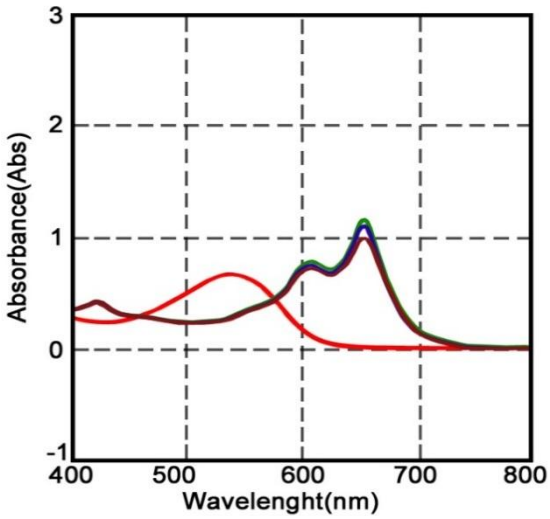
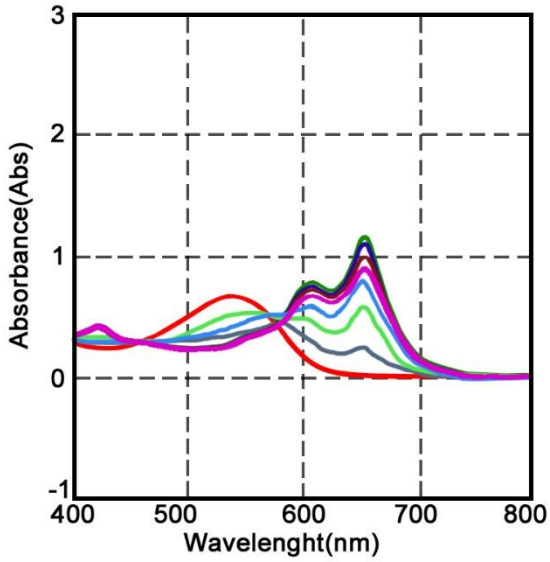
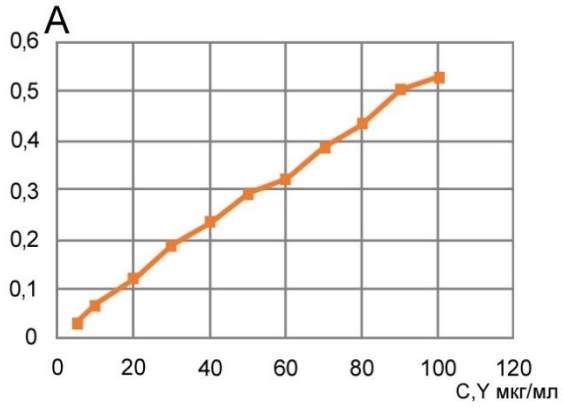


Fig. No: (2): Effect of Reagent Concentration on Yttrium Complexation

The study of the obedience of the solution of the yttrium complex with 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid to the Bouguer-Lambert-Beer law was carried out under the found optimal conditions. The results are shown in Fig. 2 and 3.



Results of the study of obedience to the Bouguer-Lambert-Beer law of the yttrium (III) complex with the reagent 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid



The solutions of the complex obey the Bouguer-Lambert-Beer law in a wide range of yttrium concentrations 1.0-90.0 μg for Y (III) in 25.0 ml of an aqueous solution.

The structure of the organic reagent and complex was proved by IR spectroscopy data.

Study of the IR spectrum of 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid has the following characteristic absorption bands (ν, cm-1): 885, 960 (1,2,3,5,6, 8-hexa-substituted naphthalene), 1625, 1650 (C-C bond in ArH), 3030 (= CH in ArH), 1500 (ν_{NO}), 3560 (ν_{NO}), 1344 (δ_{OH}), 3360 (ν_{NH2}), 1710, 1250 (δ_{NH2}),1245, 1150 (ν_{SO3H}) (Nakamotoet al.1966, Kazitsinaet al. 1971 and Bellamy et al. 1971).

The IR spectrum of the yttrium complex with 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid has the following characteristic absorption bands (ν, $см^{-1}$): 960 (1,2,3,5,6 , 8-hexa-substituted naphthalene), 1600, 1650 (C-C bond in ArH), 3033 (= CH in ArH), 1510 (ν_{NO}), 3650 (ν_{OMe}), 1340 (δ_{OMe}), 3100 (ν_{NH3}^{+}), 1770 (δ_{NH3}^{+}), 1240, 1150 (ν_{SO3H}). This proves that yttrium binds an ionic bond with a hydroxyl group, and an acceptor bond with a nitroso group.

The ratio of the components was established by the methods of isomolar series, molar ratios and equilibrium shift. In all cases, under optimal conditions, only one complex is formed with a ratio of yttrium (III) components: 2,4-dinitroso-1-hydroxy-9- aminonaphthalene-6,8-disulfonic acid = 1: 1.

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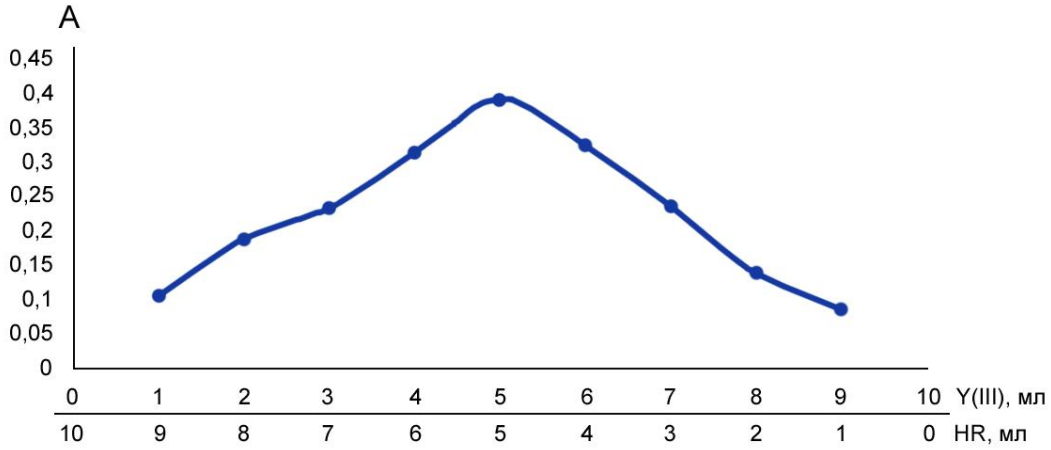


Fig. No: (5): Determination of the composition of the yttrium complex with 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid

To calculate the stability constant of the complex, we studied the dependence of the optical density of solutions of the yttrium complex with 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid on the concentration of ligands (Bulatovet al. 1987 and Kutlimurotovaet al. 2001). The true molar light absorption coefficient of the complex was found by the Tolmachev method equal to 75500. Equation 1 was used to calculate $lg\beta_{MeR}$ for each concentration of the ligand.

$$[HOL]^{2-} = C_{[HOL]^{2-}}[YOL]^{+} = \frac{A_{макс} - A_x}{\varepsilon}$$

$$lg\beta_{MeR} = lg\frac{A_{макс}-A_x}{\varepsilon} + \lg C_{[HOL]^{2-}} + \text{pH} \qquad (1)$$

Then, based on the data obtained, the dependence $lg\beta_{MeR} = f(lgC_L)$

Fig. 6. and 7.

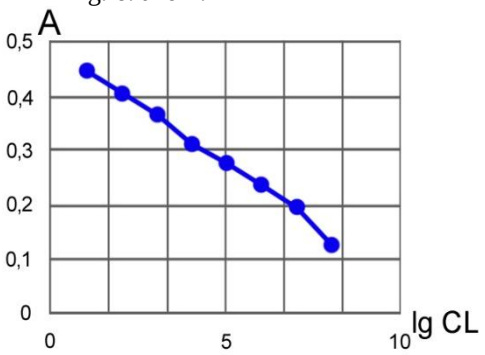


Fig. No: (6):The dependence of the light absorption of the logarithmic concentration of the ligand

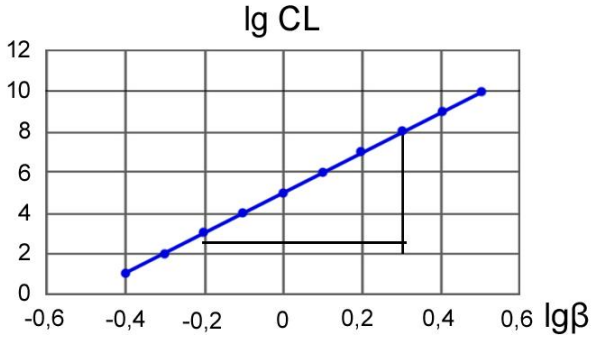
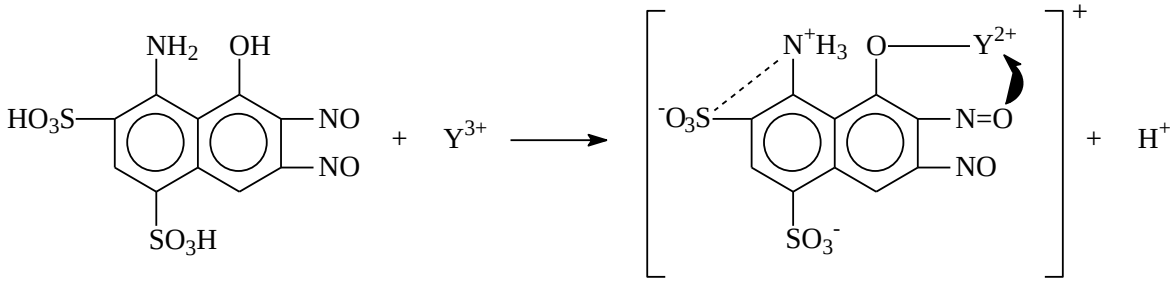


Fig. No: (7):Dependence of lgβ on the logarithmic concentration of the ligand.

The resulting converging constants confirm the reliability of the chosen complexation scheme and the stability constants of the yttrium complex with 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid. One more proof was obtained that yttrium forms with 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid a complex with a component ratio of 1: 1, since in all cases the slope of the slope in plotting the dependence$lg\beta_{MeR} = f(lgC_L)$equal to 0.8 or close to 1 and the stability constant of the complex is equal to 4.5 · 107. The complexation scheme is shown in the diagram.



Scheme of the complexation of yttrium with 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid

$$Y^{3+} + [HOL]^{2-} \rightarrow [YOL]^{+} + H^{+}$$

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With the aim to assess the degree of selectivity of the proposed methods for the determination of Y (III) with a solution of 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid. To check the possibility of its increase by introducing into the analyzed solution of extraneous cations accompanying them in nature, a method was carried out for the determination of yttrium by a series of experiments with the spectrophotometric investigated metals in the presence of increasing amounts of a number of foreign and interfering cations as well. It was found that the determination of Y (III) does not interfere with (мкг): 20 (In), 56 (Fe), 40 (Th), 10 (Sc), 10 (La), 25 (Zr), 130 (Cr), 55 (Co), 112 (Cd).

When determining Y (III) in ores, such as lanthanides, coffinite, containing the main components in quantities (μg) (Ore deposits of Uzbekistan. Directory 2001): Y –1.12; V2O5 -1.06; MoO3 -1.26; Tb -0.16; Sc - 0.5; Cd 0.10; Se - 0.08; Re - 0.09; Co - 0.078, results with high metrological characteristics were obtained, the data of which are given in table 8.

Table No: (1): Spectrophotometric results of determination of yttrium in ores (P=0,95, $\bar{x} \pm \Delta X$)

Composition of associated components in ores, μg	Found yttrium, μg / l		n	S	Sr
	The developed method	Atom absorption method (control method)			
Y(1,12)+Sc(0,5)+ +Tb(0,16)+Cd(0,10)+Ce(0,180)	1,09	1,13	3	0,03	0,048
	1,11	1,08			
	1,13	1,12			

From the data in the table it can be seen that reliable, reliable, correct and reproducible results were obtained in the determination of yttrium with a solution of 2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid by spectrophotometry.

CONCLUSION

From the data obtained, it can be concluded that the new synthesized organic reagent-2,4-dinitroso-1-hydroxy-9-aminonaphthalene-6,8-disulfonic acid is sensitive for the determination of trace amounts of yttrium (III). The spectrophotometric technique is used in the analysis of ores; the relative standard deviation does not increase 0.33. The developed techniques can be applied with great success to the analysis of real natural objects and industrial materials.

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